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Malcolm Baldrige National Quality Award 2007 Award Recipient

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Nanotechnology Capabilities at Picatinny Arsenal

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Agenda

- Background Information
- Nanomaterials
- Picatinny's Production Capabilities
  - Bottom Up
  - Top Down
- Picatinny's Characterization Capabilities

Powder technologies are an integral part of Picatinny's Mission

About Picatinny

Picatinny Arsenal

- "Home of American Firepower"
- Baldrige Award Winner
- Improving legacy items
- Developing new items
- Prototyping capability
- Fill technology gaps

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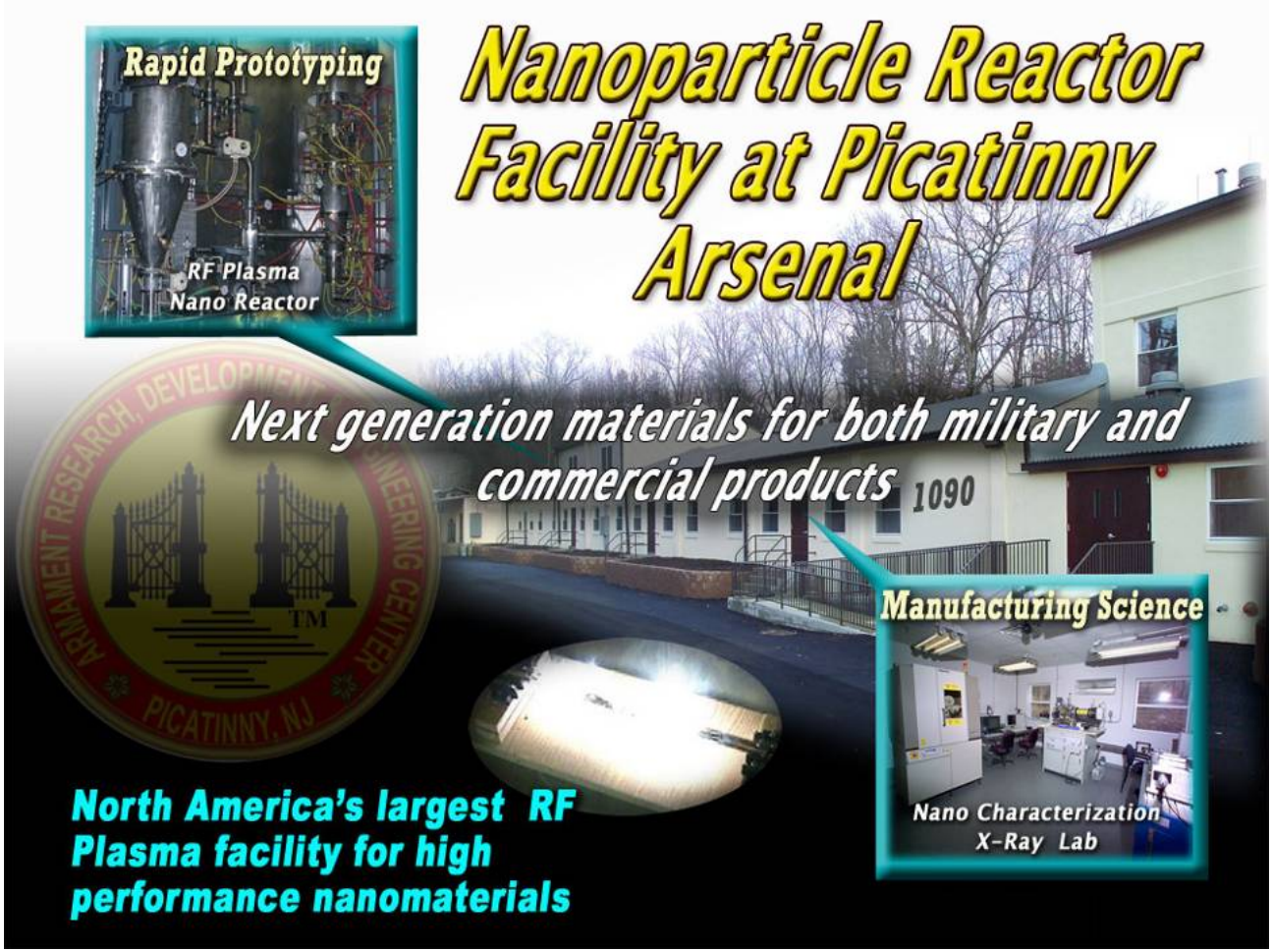
Nanotechnology Facility



An integrated state-of-the-art facility to synthesize, process, and characterize nanophase and nanostructured materials, fully dense near-net shape bulk components, and nanostructured coatings

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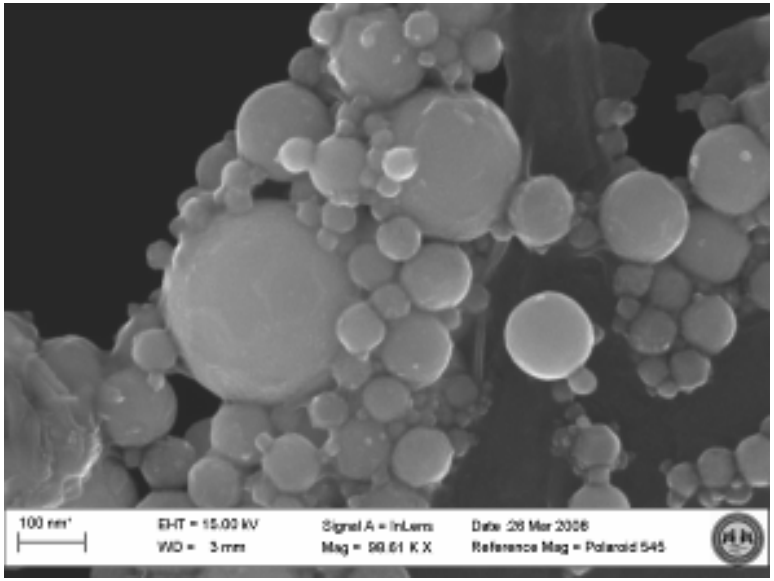
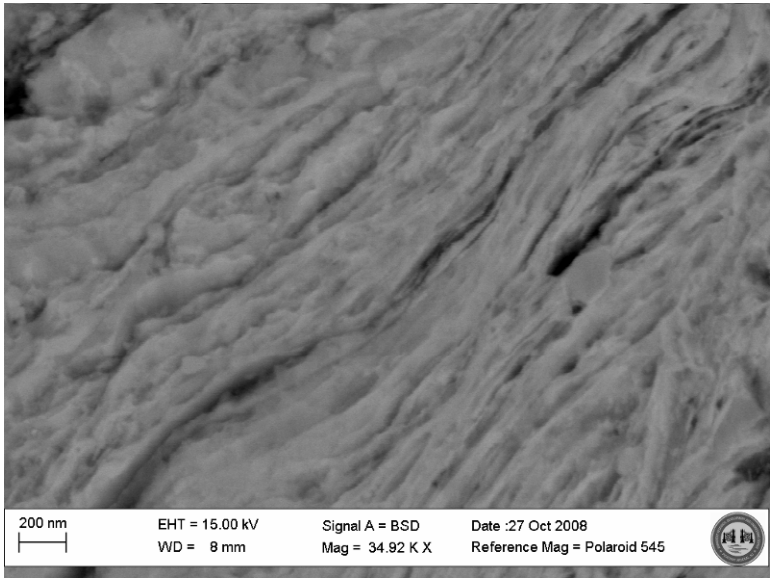
Nanomaterials

- Nanophase Materials
  - Materials having nanoscale primary particle size



- Nanostructured Materials
  - Materials which are not necessarily nanoscale but possess features which are on the nanoscale.



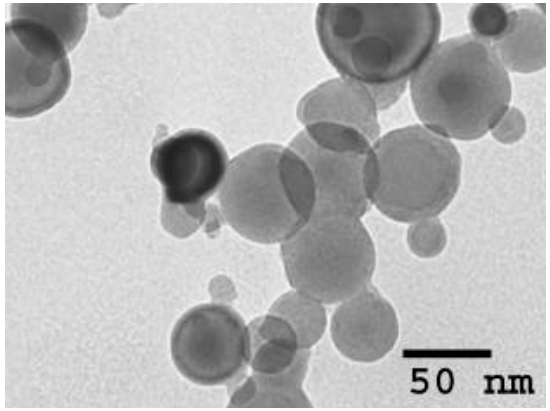
Perspective

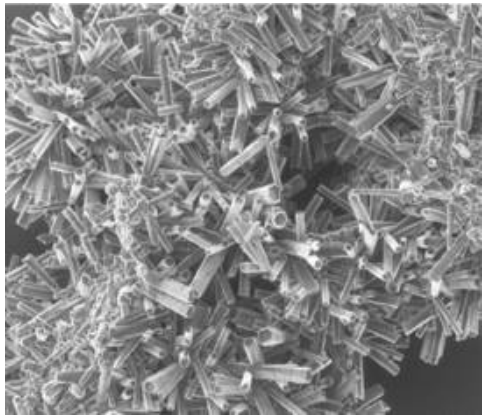
- Nanomaterial – a material having at least one dimension in the 1-100nm range
- Thickness of paper = 100,000nm
- Thickness of a human hair = 50,000nm
- Comparing a nanometer to a meter is like comparing a soccer ball to the earth
- There are 25,400,000 nanometers in 1 inch

Nanotechnology is a natural extension of particulate technology.

Novel Materials

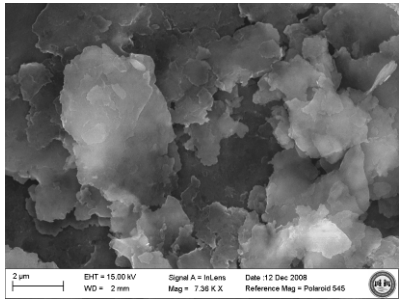
- What happens on the nano scale
  - Tunable properties → Particle morphology
  - Higher strength
  - Reduced Weight
  - Increased reactivity → Increased surface area
  - Increased durability

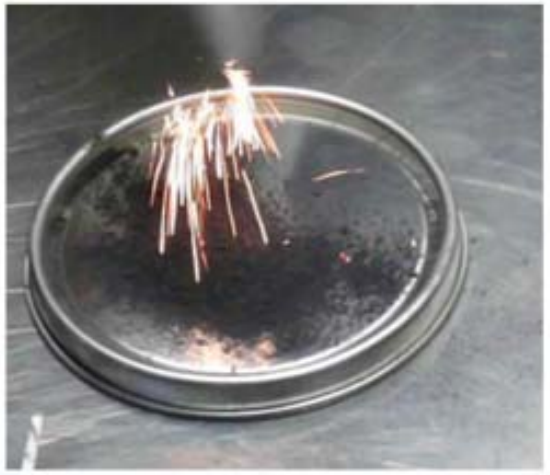




Anti-Corrosion Applications

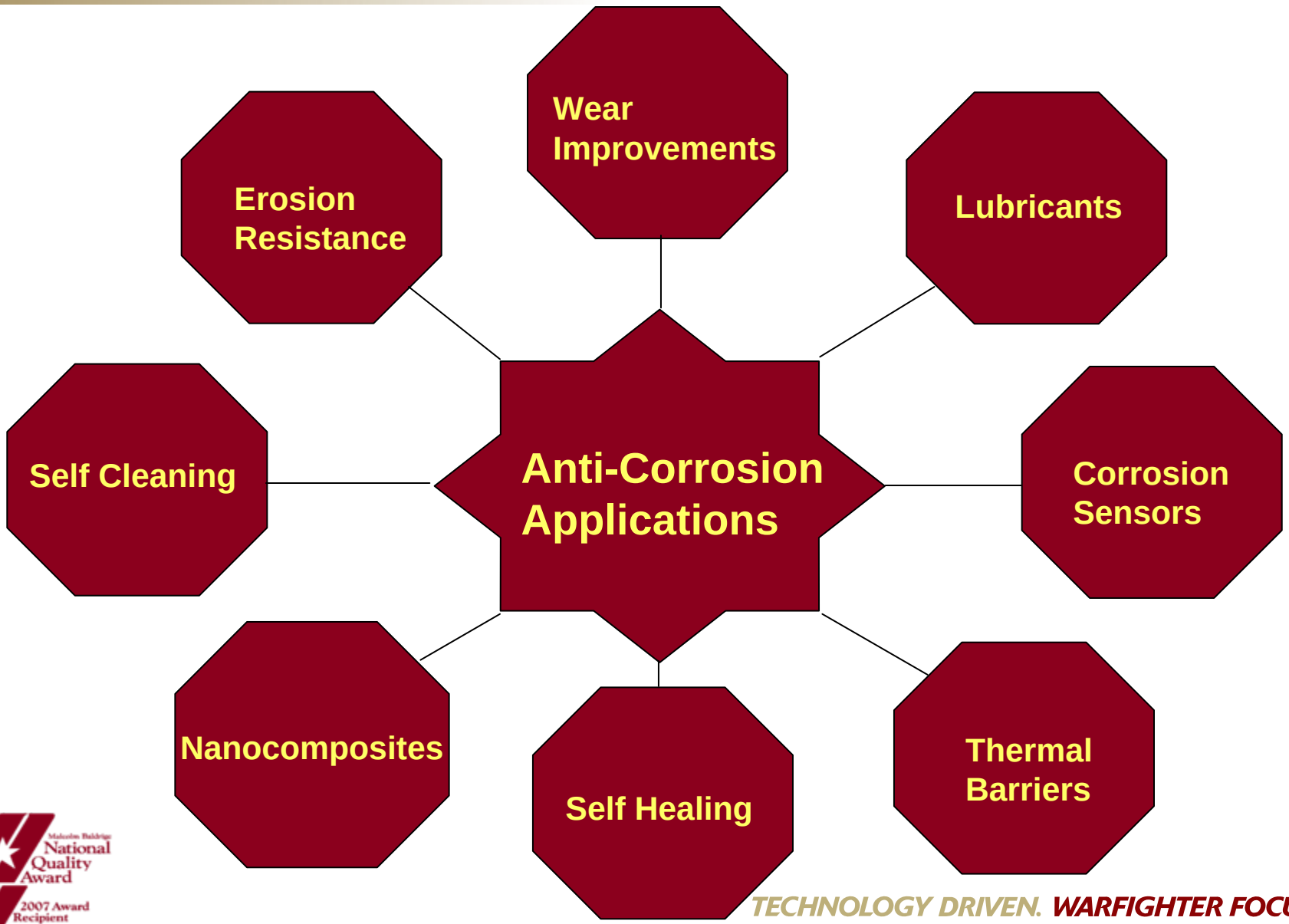
- Take conventional anti-corrosion techniques and scale down to the nano level
- Multi functionality as well as improved functionality
- Traditional properties may no longer apply between bulk and nanoscale
  - Materials become transparent
  - Materials become pyrophoric





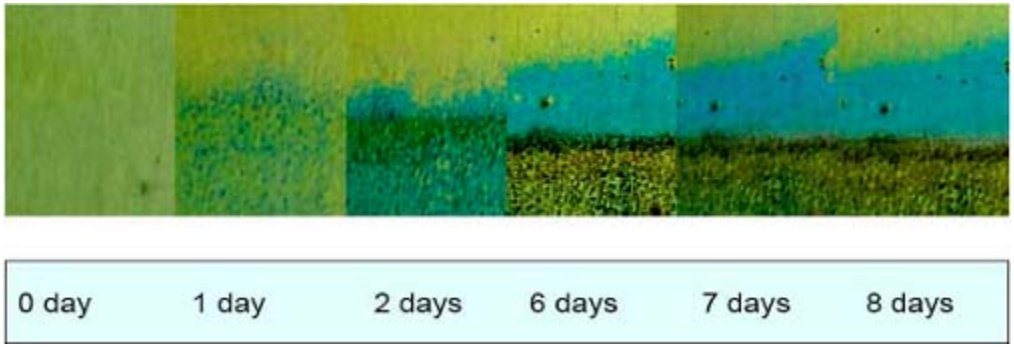
- **Surface modifications, protection, and functional coatings utilize powders and particulate technology**

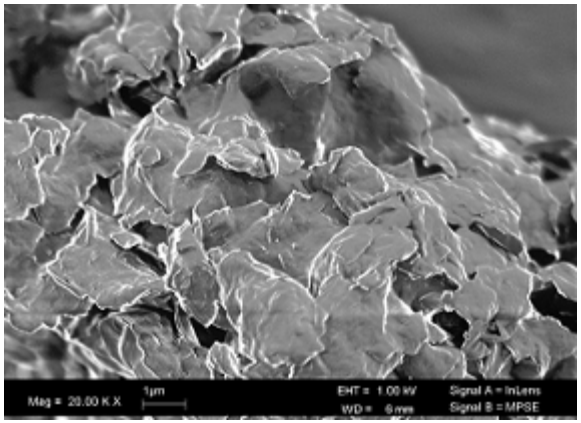
Nano & Coatings



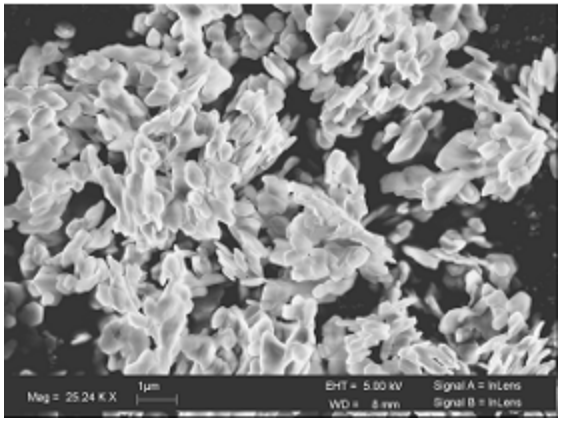
Nano i-clays Corrosion Indicator

Results after accelerated corrosion testing





Montmorillonite (Cloisite 15A) / 5% Bromothymol Blue



Hydrotalcite / 5% Thymophthalein

Nanomaterials Synthesis Technology

- Bottom Up Approach

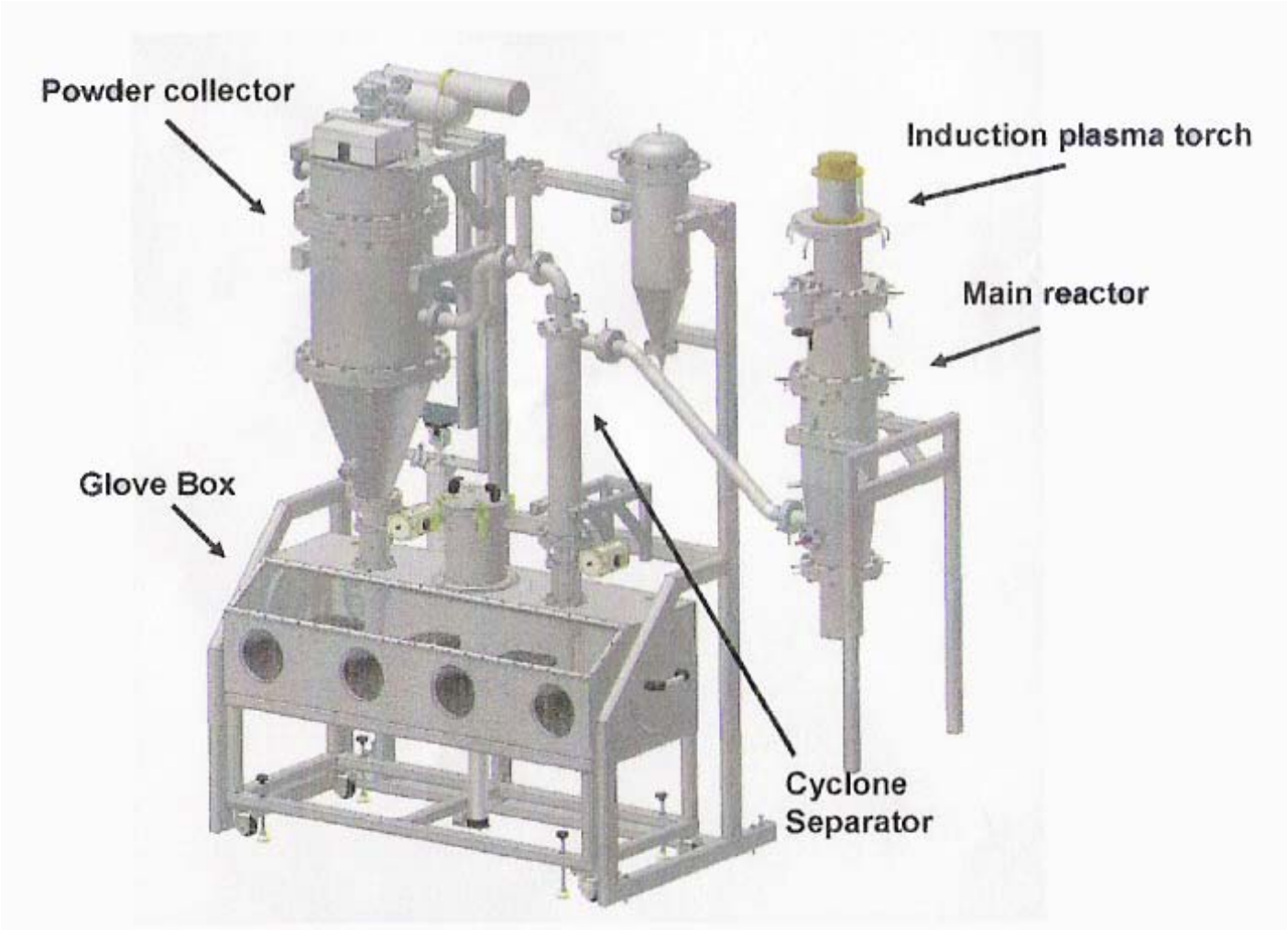
- Top Down Approach

Using thermal plasma technology to synthesize nanomaterials is at the heart of our prototyping facility.

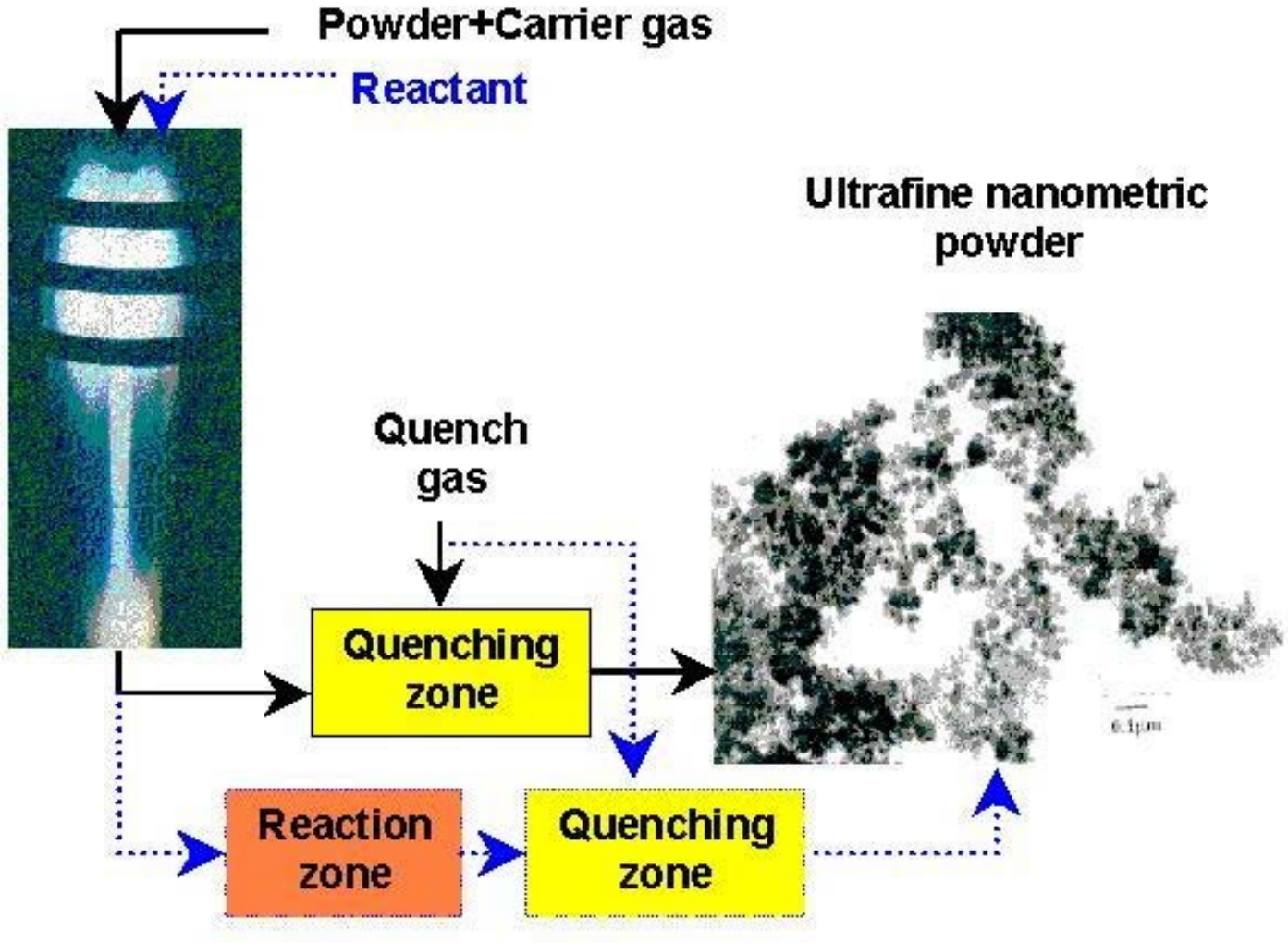
Inductively Coupled Plasma

- Induction Plasma is a versatile and high rate technology to synthesize nano scale powders

Reactor Layout

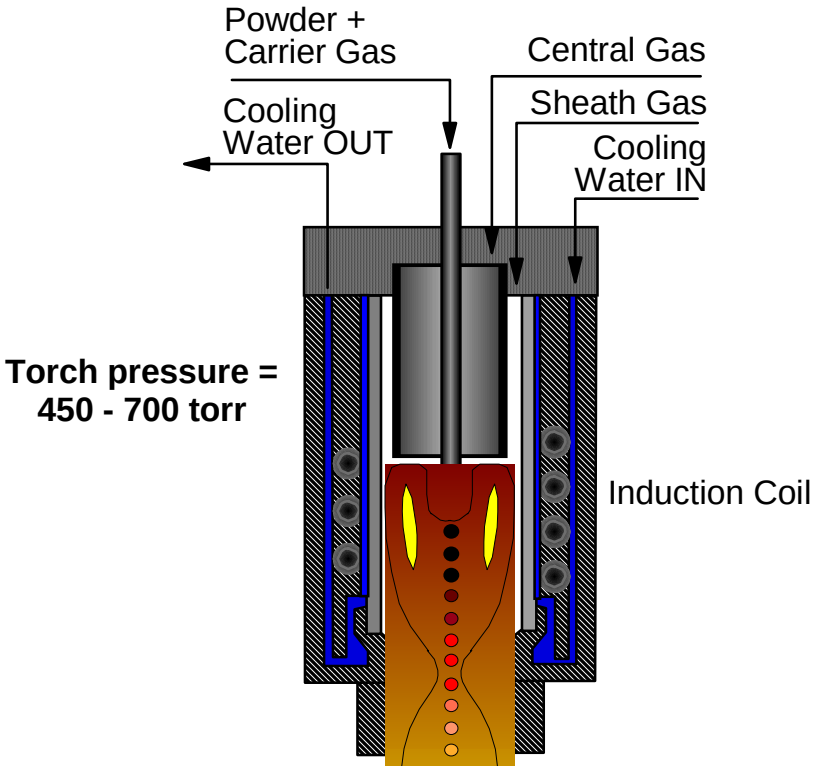


Plasma Theory



Benefits

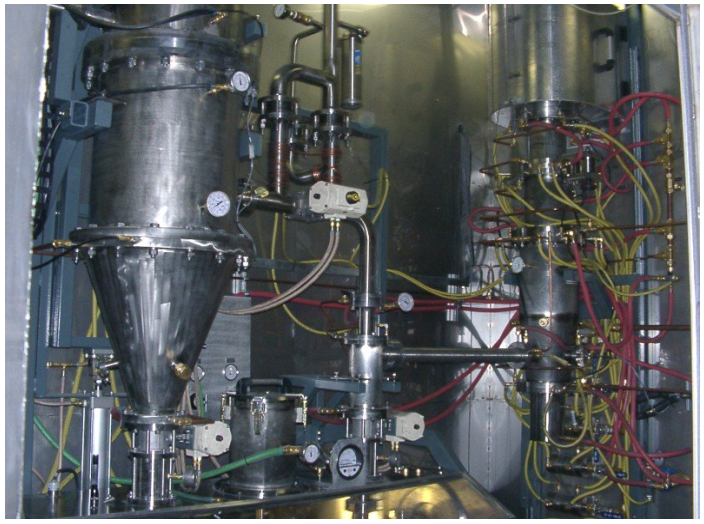
- Plasma Technology Benefits
  - Powder or liquid feed stock
  - No limit on material type
    - Over 10,000k plasma temperature
  - High purity production
  - Flexibility of operating conditions



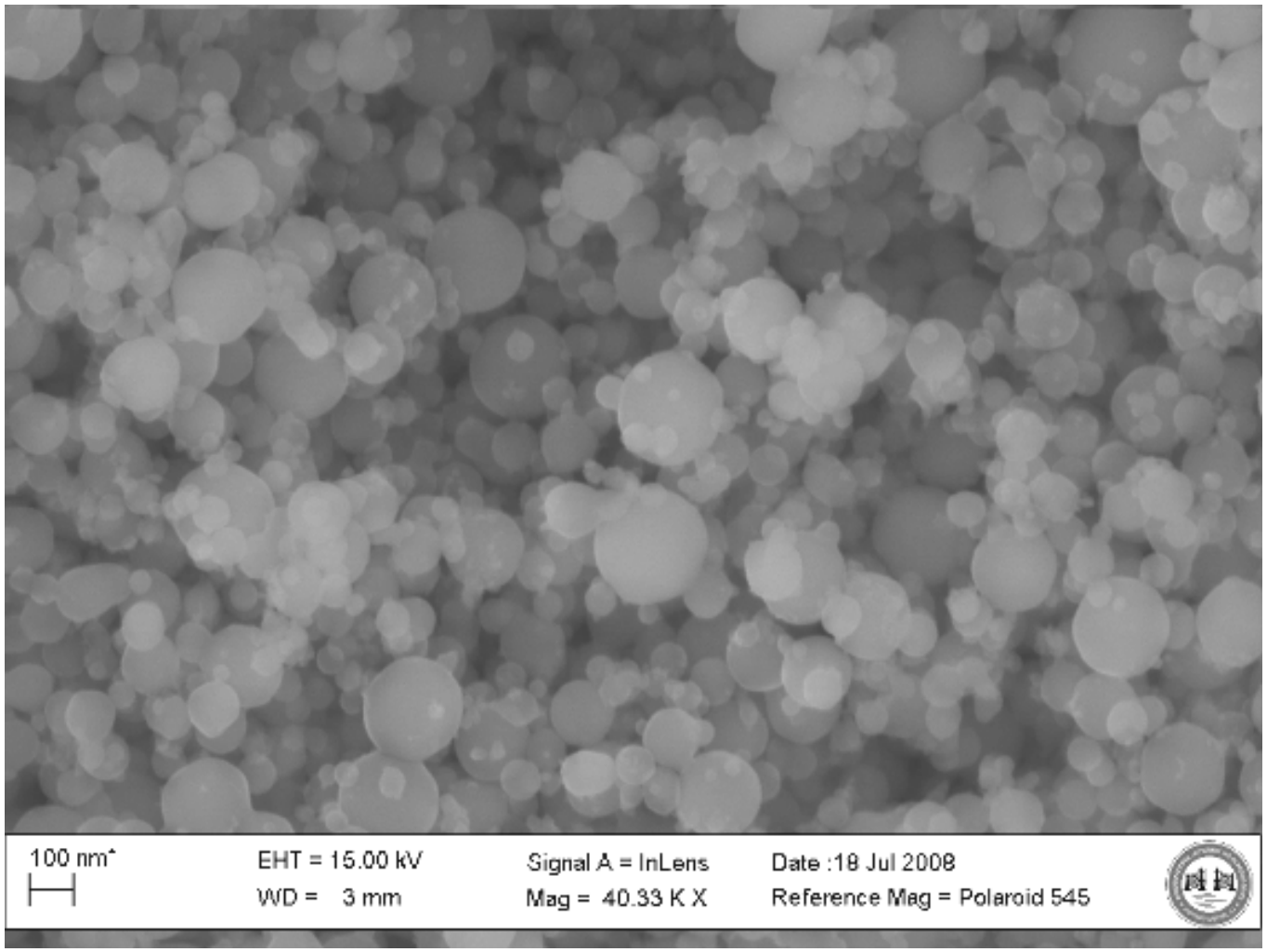
Capabilities & Accomplishments

- Two Plasma Reactors
  - One unit for metals only
  - One unit for ceramics and non oxides
  - Production rate: up to 1kg/hr

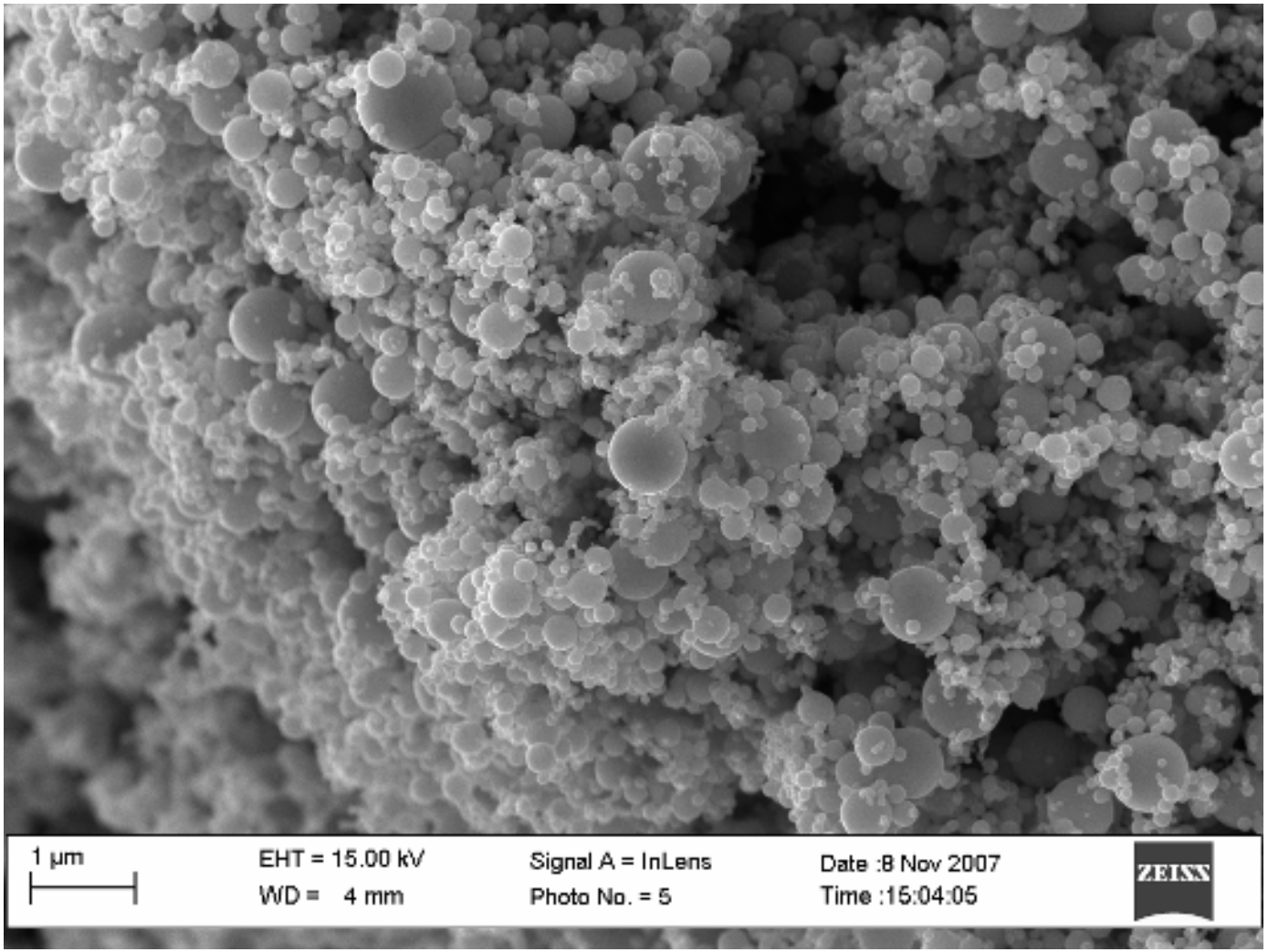
- Some nanoscale powder examples
  - Aluminum
  - Tungsten
  - Cerium Oxide
  - Boron Carbide
  - Iron



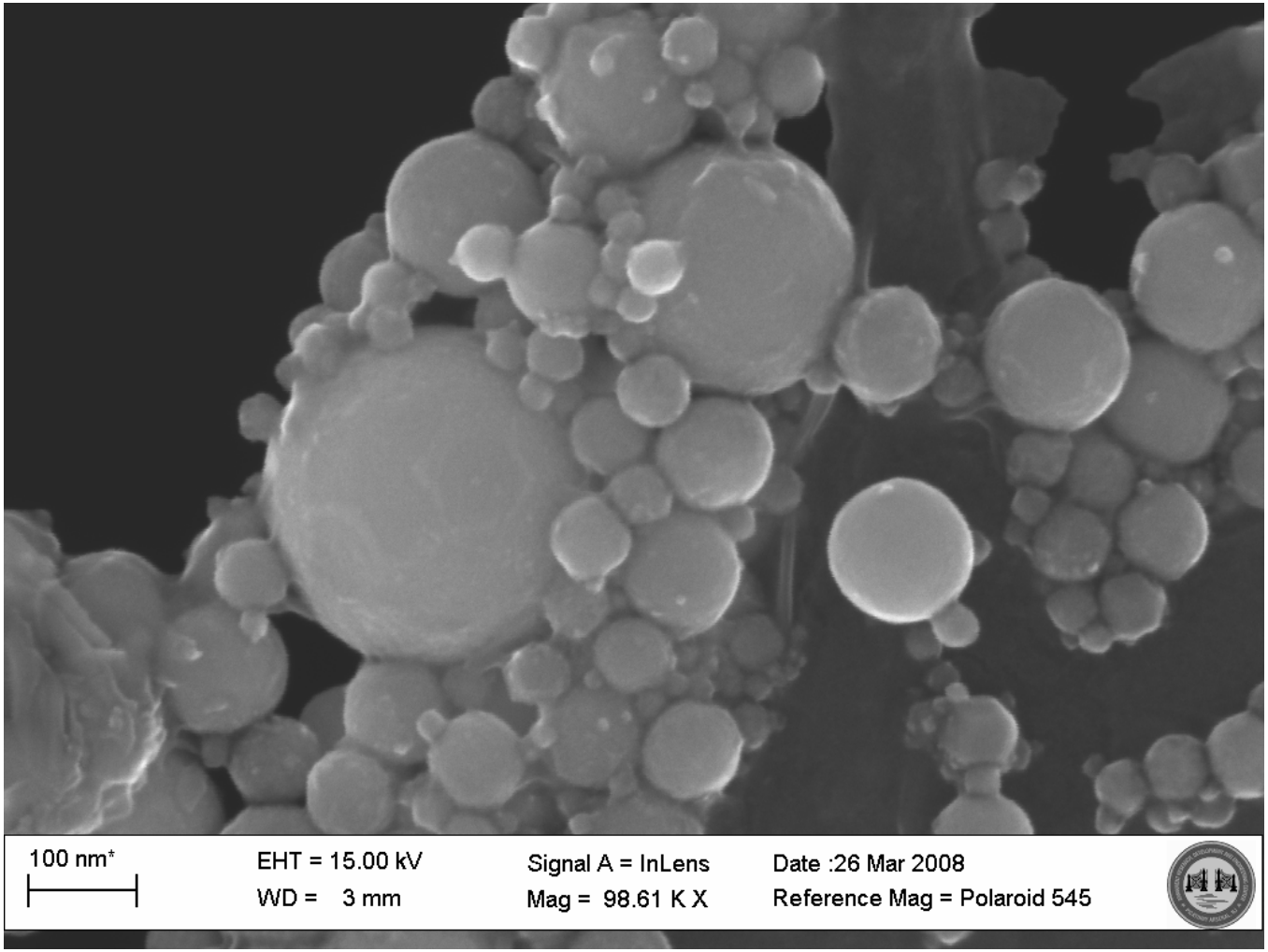
Nano Aluminum



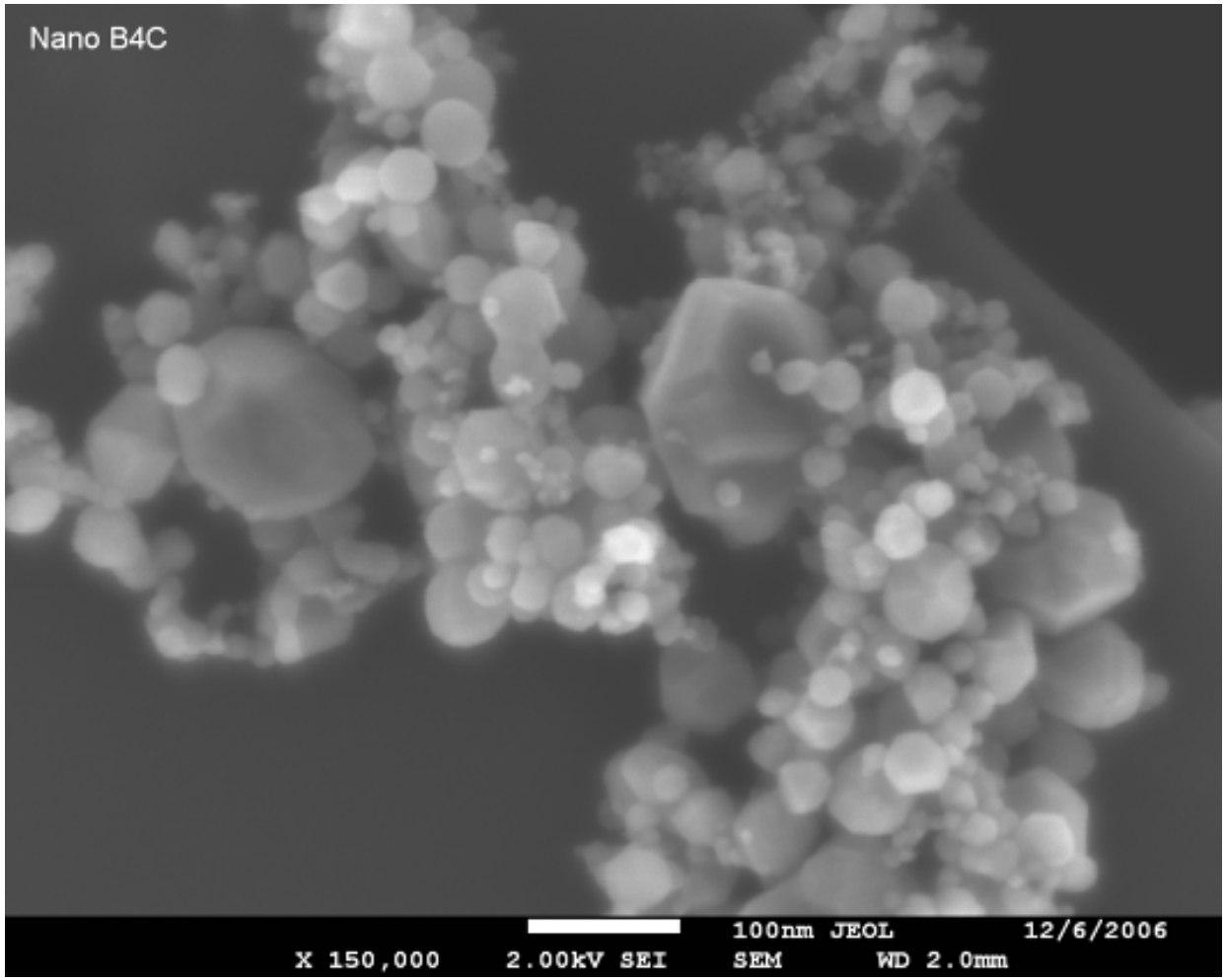
Nano Iron



Nano Tungsten



Nano Boron Carbide



Mechanical Alloying

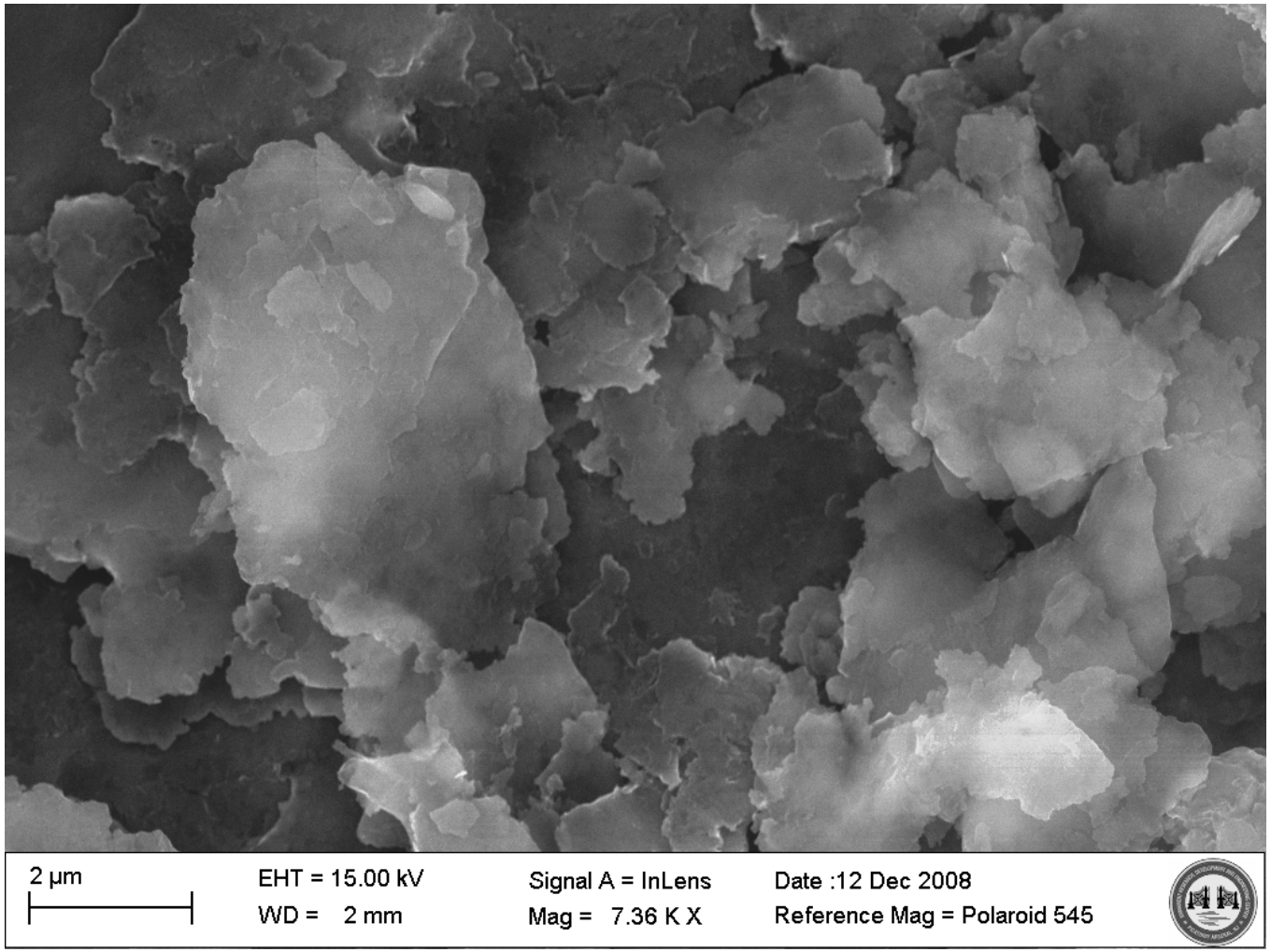
- High energy milling is a top down approach to fabricate nanostructured metals, alloys, ceramics, cermets, and reactive materials.

Capabilities

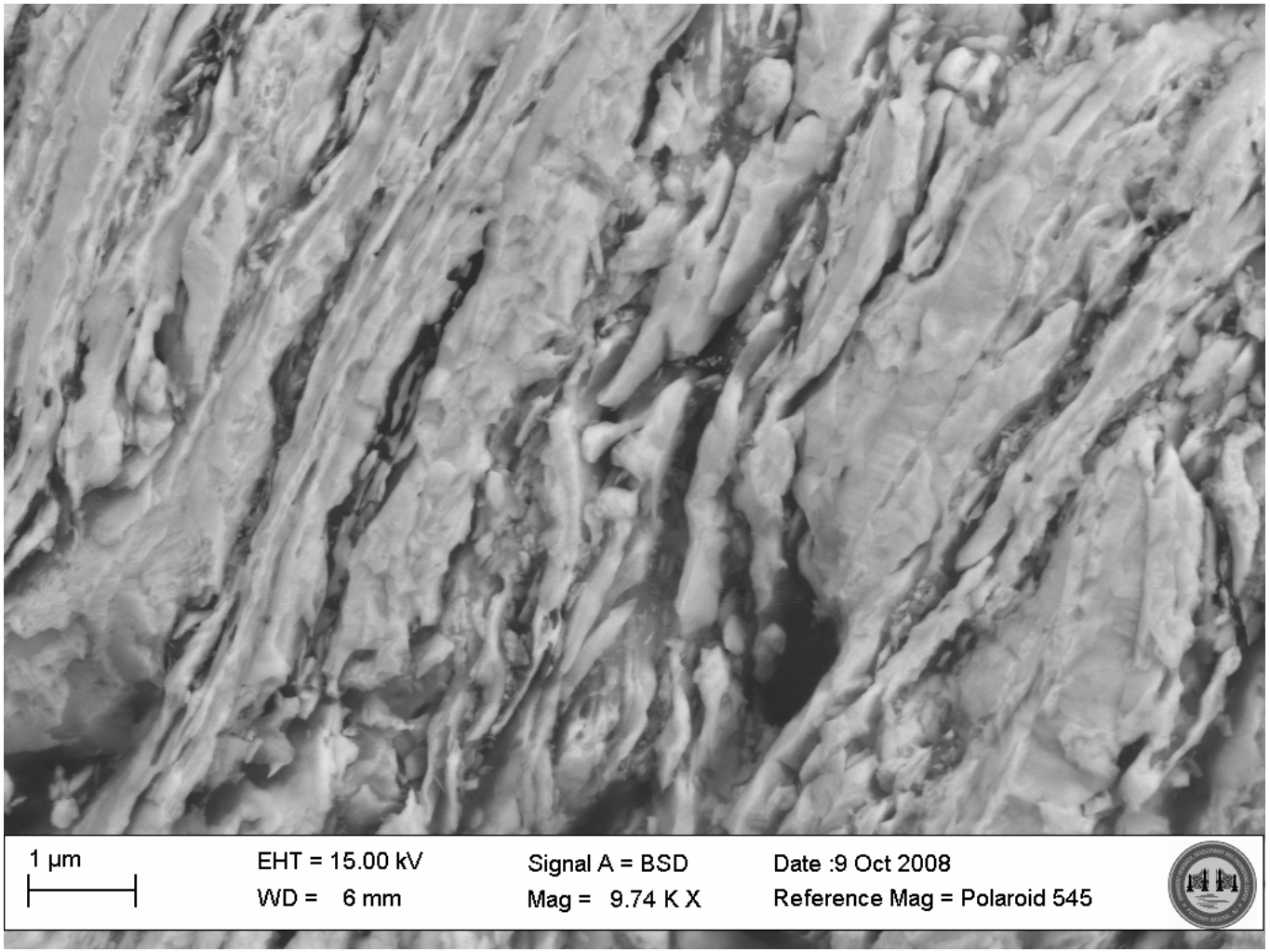
- Inert atmosphere for reactive materials
- Semi-continuous prototyping capability
- Experimental batch capability
- Tailor made compositions
- Three total units
  - Two (2) one liter machines
  - One (1) 8 liter machine

- **Able to impart nano sized grains into micron sized powders**

Nanostructured Aluminum Flakes

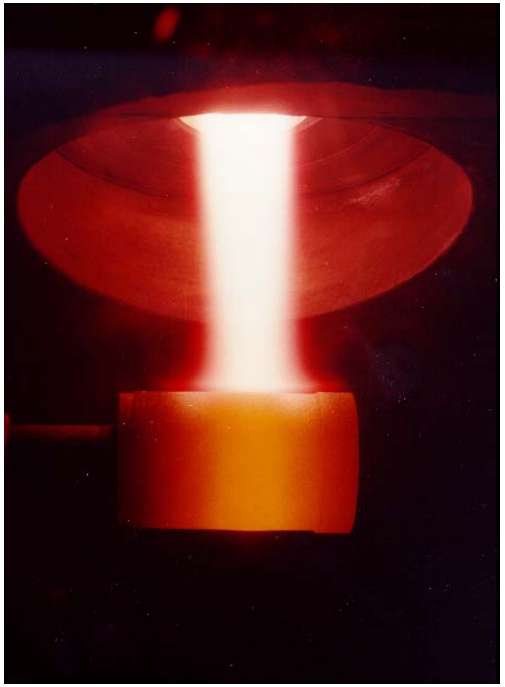


Nanostructured Alloys



Using Plasma for Coatings

- Coatings can be applied via liquid or vapor deposition
- VPSD (Vacuum Plasma Spray Deposition)
- Can be used to net shape bulk products or apply coating layers

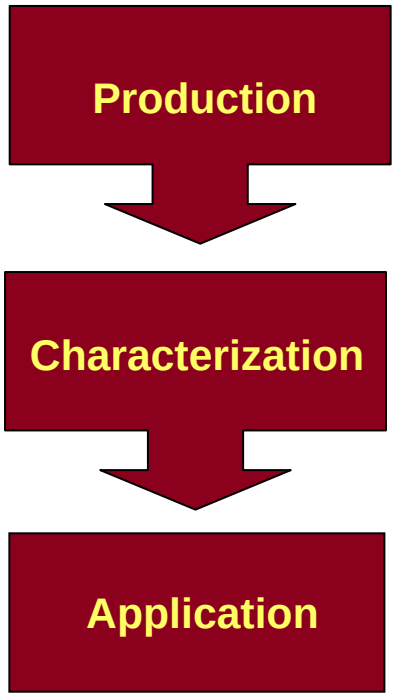


Characterization Facilities

- Current equipment:
  - Field Emission Scanning Electron Microscope
  - X-ray Fluorescence
  - X-ray Diffractometer
  - Small angle X-ray scattering & Ultra small angle X-ray scattering
  - Thermal analysis equipment

Materials Properties of Interest

- Particle size and distribution
- Composition
- Morphology
- Surface Area
- Thermal Properties
- Passivation layer thickness
- Crystallite size
- Phase identification



- Picatinny's facilities allow for rapid characterization of materials as soon as they are made.

Field Emission Scanning Electron Microscope

- Zeiss Gemini Ultra Variable Pressure FE-SEM with EDX
  - Capable of low voltage
  - VP mode
  - STEM attachment
  - 1nm resolution @ 20kV
  - 12-1000000x magnification
  - High efficiency in-lens
  - Secondary and Backscatter
  - Used to determine:
    - Particle size
    - Distribution
    - Morphology
    - Passivation layer
    - Composition

X-Ray Fluorescence

- Rigaku ZSX Primus II X-ray Fluorescence
  - Capable of holding up to 64 samples
  - Quantitative analysis results
  - Composition determination
  - Solid, liquid, or powder samples

X-Ray Diffractometer

XRD Unit

SAXS

USAXS

- Rigaku Ultima XRD
  - Determines phase and crystallite size
  - Bulk sample holder
  - Hot stage
  - 6 ring powder sample holder

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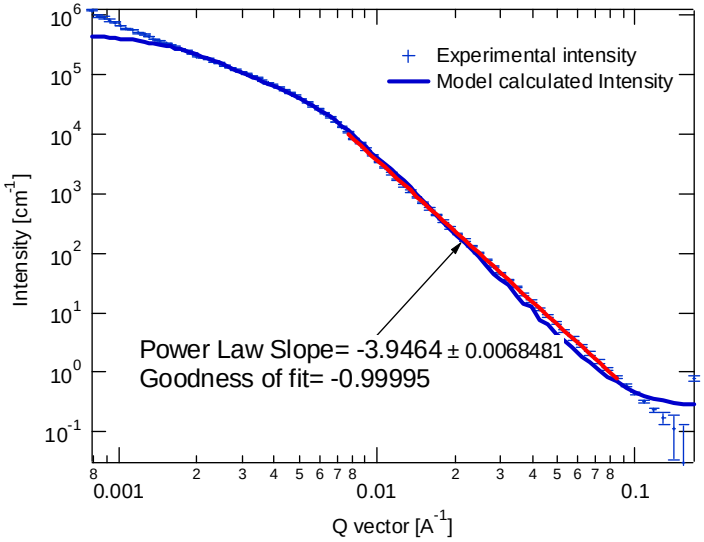
SAXS & USAXS

- Combining Small Angle and Ultra-small Angle X-ray Scattering allows *simultaneously* characterizing
  - Primary, secondary particle size & particle morphology
  - User friendly software developed
  - Total length scale, 1 nm – 2 µm

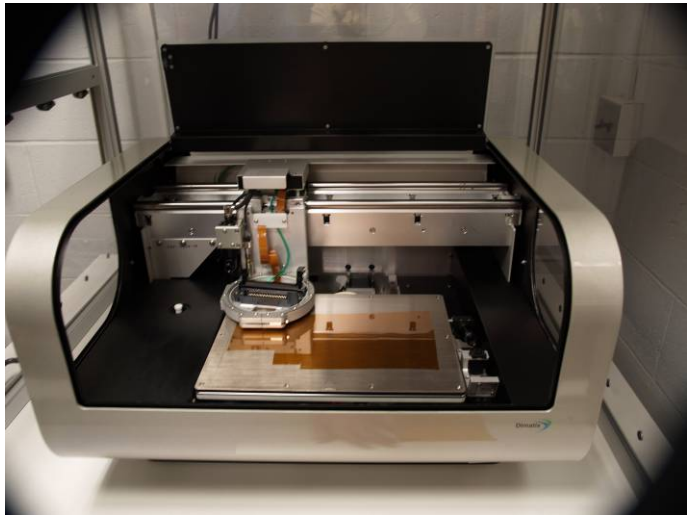


Thermal Analysis

- Netzsch STA 449 C Jupiter – QMS 403 Aeolos Integrated TG-DSC / Mass Spec
  - Thermal properties
    - Oxidation
    - Exotherms
    - Endotherms
    - Melting Point
    - Moisture content
    - Organics content
  - Aging characteristics
  - Passivation layer thickness

Other Equipment

- Nano ink printer
- Low voltage electron microscope
- Optical Microscopes
- Polishing and grinding units
- Spray dryer
- BET
  - Surface area
- Glow Discharge
  - Composition
- Oxygen analyzer



Summary

- **Powder Production Capability**
  - Able to produce nanostructured materials with enhanced properties using high energy milling.

  - Able to produce almost any nano scale powder at a rate up to 1kg/hr for potential applications involving anti-corrosion technologies.

- **Materials Characterization Capability**
  - Collaboration also available for corrosion mechanism identification

  - Able to obtain vast amounts of information about bulk materials or nanomaterials in a short time.

THANK YOU

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